Methane emission from tropical savanna Trachypogon sp. grasses

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Abstract

Methane flux measurements from the soil-grass system were made during the wet season in unperturbed plots and plots where standing dry and green *Trachypogon sp.* grasses were clipped to just above the soil surface. Results support the surprising discovery that vegetation emits methane. The dry/green mixture of grasses produce methane at a rate of ∼10 ng m^{-2} s^{-1}, which extrapolated to the global savanna would produce an annual emission of ∼5 Tg, much lower than the production recently suggested in the literature. On the other hand, during the wet season savanna soil consume CH_4 at a rate of ∼4.7 ng m^{-2} s^{-1}, producing a global sink of ∼1.3 Tg yr^{-1}. Therefore, the tropical savanna soil-grass system would make a modest contribution to the global budget of methane.

1 Introduction

Methane is an important greenhouse gas, whose radiative forcing (1750–1998) has been estimated to be 0.48 Wm^{-2}, ∼20% of the total positive forcing produced by long lived gases and tropospheric ozone (Ramaswamy et al., 2001). The methane budget (sources and sinks) was believed to be relatively well known, however, recently a surprising discovery, based on laboratory measurements, indicated that land plants would emit methane in significant quantities, up to 30% of the present evaluated global sources (Keppler et al., 2006). Methane emissions from vegetation may explain early field results from tropical ecosystems (Crutzen et al., 2006) and recent satellite observations (Frankenberg et al., 2005). In the past, erratic and sometimes confusing results were obtained in studies of CH_4 soil fluxes in the Venezuelan savanna region (Hao et al., 1988; Scharffe et al., 1990; Sanhueza et al., 1994a). On average a net emission of methane was reported, however, quite often consumptions from individual plots were registered. According to Sanhueza et al. (1994a), these results are in contrast to the general belief that non-flooded soils of temperate, subtropical, and tropical regions only act as sinks for atmospheric methane. The authors speculated that, by an unknown mechanism, the methane emitted in the Venezuelan savannah region could be produced by biogenic activity. Now, after publication of the Keppler et al. (2006) paper, showing that both living plants and plant detritus produce methane, it is clear that the soil-grass system is more complex than previously believed. In addition to soil processes (e.g., population of methylotrophic bacteria) other aspects (e.g., presence of living or dead plants) must be taken into consideration, to understand/explain the CH_4 flux variability. In this paper we report a study of the soil-grass system in the central savanna region of Venezuela, made in 1990, which allows to infer the role of grasses in the fluxes of CH_4 from the soil-grass system.

2 Field measurements

The study was performed during the 1990 wet season at the Estación Biológica de los Llanos, located in the central part of the Venezuelan savannah climatic region (8°53′ N; 67°19′ W). Two well defined climatic periods occur in the area: a dry season from December to April and a rainy season from May to November. The annual rainfall is 1300 mm and the annual mean temperature is 27.6°C. Soils are acidic, with a low rate of mineralization and poor in nutrients. They support graminea grasses (mainly *Trachypogon sp*. and *Axonopus canescens*) interrupted by trees and scrub (*Curatella americana, Boudichia virgilioides* and *Byrsonima crassifolia*). Physical and chemical properties of the soils, obtained from soil samples of 10 cm depth, were given by Sanhueza et al. (1994b).

Fluxes from the soil-grasses system were measured using the enclosed chamber technique; the stainless steel glass chamber and other details were similar to those described by Conrad and Seiler (1985). During measurements the chamber was covered with aluminum foil. CH_4 was analyzed by gas chromatography, using a flame ionization detector. Other experimental/analytical details are given by Scharffe et al. (1990). Gas samples were automatically supplied to the chromatograph injection valve and recirculated back to the chamber at a flow rate of 250 mL min 1. The gas stream passed through a cold trap at 78°C to remove water.

A particular plot was measured for ~60 min, during which the following samples were injected to the gas chromatograph: one sample of ambient air, seven samples from the chamber (1 every 6 min), and two samples of calibration gas. To initiate measurements, the chamber was placed manually over the frame; after measurements were made the chamber was moved to another frame and the process repeated. Most experiments show that after the chamber was closed, variations (increase or decrease) in the concentration were observed. After a relatively short period, changes in concentrations decline and fluxes (emission or consumption) were calculated using only the fourth initial points of a particular run. Gravimetric soil moistures were measured in samples of 2 cm depth. Soil temperature at 1 cm depth was recorded continuously during flux measurements with a thermocouple.

3 Results

Methane flux measurements were made in four unperturbed plots and three plots where standing grasses were clipped to just above the soil surface and plant litter removed from the soil surface (cleared plots). In the unperturbed plots there was a representative amount of *Trachypogon sp.* grasses, which is the most abundant natural grass in the region. Since the study was made in an area which was not burned the previous dry season, dry dead standing grasses were mixed with green ones; in average 46% (dry weight) was dry grass.

Individual flux measurements are shown in Fig. 1. In the figure is also indicated the rainfall that occurred during the measurement period; average soil moistures during the rainy days (23–26 Oct.) was ~8% and ~3% during the less rainy period (1–7 Nov.). Under this soil moisture conditions there should not be any gas transport limitation between atmospheric CH_4 and the soil bacteria (Striegl, 1993; Castro et al., 1995).

The averaged flux for the unperturbed plots (Fig. 1a) shows a net production of

ACPD
6, 6841–6852, 2006

methane from the soil-grass system of 6.0 ng m^{-2} s^{-1}, with an standard error of 2 (n=34). On the other hand, as presented in Fig. 1b, the perturbed-cleared plots showed a clear consumption of CH_4 with an average of –4.7 ng m^{-2} s^{-1}, with an standard error of 0.9 (n=30). Therefore, under regular field conditions, the soil-grass system emit CH_4, most likely due to methane production from grasses (Keppler et al., 2006), whereas cleared savanna soil consume methane; most likely due to the activity of methylotrophic bacteria in aerated soils (Conrad, 1996; Hanson and Hanson, 1996).

In Keppler et al. (2006) laboratory experiments, the exposition of live or dead plants to solar radiation induced a large increase of the emission of methane, which continued by a relatively long period of time (~15 min) after the light was off. As mentioned, in our field CH_4-flux measurements the chamber was covered with aluminum foil, however, since plants or detritus present in the experimental plots were exposed to the sun light until the chamber was set in position, the fluxes calculated using the firsts four time points (including the initial atmospheric concentration) should adequately contemplate the effect produced by the solar radiation.

CH_4 fluxes plotted as a function of soil temperatures are shown in Fig. 2. In general, in the undisturbed plots (Fig. 2a) methane emission was observed at temperatures lower than ~30°C, whereas consumption was recorded at higher temperature. This could mean that at high temperatures live grasses decrease the production of methane (likely due to physiological stress) and/or that the bacteria activity, which consumes methane, increases. According to Hanson and Hanson (1996) different soils exhibit different methane oxidation responses with respect to temperature, indicating that populations of methanotrophs in nature could adapt to different temperatures; methane consumption in cleared soil (Fig. 2b) presents a weak positive correlation with soil temperature, similarly to findings of Koschorreck and Conrad (1993) in different German soils.

4 Discussion

4.1 Methane consumption by savanna soils

Results from cleared plots indicate that savanna soils consume methane under wet season conditions. The clearance of the savanna soil surface (grasses and litter) by burning also produces a significant reduction of the methane production from the soil-grass system (Poth et al., 1995; Zepp et al., 1996); actually, at the cerrado site in Brazil, the burned soil consume methane, whereas the unperturbed soil produce CH_4 (Poth et al., 1995), in good agreement with our clearing experiment at the Calabozo site.

The consumption rate of –4.7 ng m^{-2} s^{-1} obtained in this work, during the wet season, is in the range of consumptions reported by Seiler et al. (1984) in soils of a broad-leafed savanna in South Africa. On the other hand, evidences under very dry conditions (Hao et al., 1988; Zepp et al., 1996) suggest that the consumption of atmospheric methane by savanna soils would be negligible during the dry season, most likely due to an inhibition of the soil microbial processes under dry conditions. Extrapolating the wet season (7 months) consumption rate, to the world savanna, produces a soil savanna sink of methane of ~1.3 Tg yr^{-1}.

4.2 Methane production by savanna grasses

Emission of methane from tropical savanna soils have been reported at sites in Venezuela (Hao et al., 1988; Scharffe et al., 1990; Sanhueza et al., 1992), Brazil (Poth et al., 1995) and South Africa (Zepp et al., 1996), which now should be interpreted as fluxes from the soil-grass system. In Table 1 are summarized the fluxes from the soil-grass system reported in the literature, which are in relatively good agreement with the emissions rates observed in this work The scarce data suggest that higher emissions of CH_4 are produced during the dry season; in this case the production of methane should be less compensate by a lower (or negligible) soil consumption.

The results obtained from unperturbed (6.0 ng m^{-2} s^{-1}) and cleared (–4.7 ng m^{-2}

ACPD
6, 6841–6852, 2006

Methane emission from savanna grasses

E. Sanhueza and L. Donoso

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◀| |▶
◀ ▶
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

EGU

s^{-1}) plots indicate that the mixture of green and dry *Trachypogon sp.* grasses produce methane at a rate of 10.7 ng m^{-2} s^{-1}, during the wet season; supporting the surprising discovery by Keppler et al. (2006) that vegetation emits methane. Assuming negligible soil consumption during the dry season, a quite similar production of methane from grasses is derived (see Table 1). Considering that during the dry season there is a larger proportion of dry grasses, the results suggest that both dry and green grasses should produce methane at similar rates. Assuming similar emissions (~10 ng m^{-2} s^{-1}) during dry and wet seasons and that this flux is representative of the world savannas, with a total area of 15×10^6 km^2, a global emission of methane from savanna grasses (green plus dry) of ~5 Tg yr^{-1} is estimated. This annual emission is higher than the value given by Keppler et al. (2006) for tropical savanna and grassland leaf litter (mean: 1 Tg yr^{-1}), but lower than the one for living biomass (mean: 29.2 Tg yr^{-1}).

In conclusion, our results suggest that savanna grasses made a modest contribution to the global emission of methane (~1%), which is in part additionally compensated by soil consumption during the wet season. The low production of methane from tropical savanna grasses is in agreement with results obtained at temperate grasslands(Mosier et al., 1991, 1997) and tropical pastures (Keller and Reiners, 1994; Mosier and Delgado, 1997), mainly indicating that the soil-grass system of these ecosystems consume methane.

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References

Castro, M. S., Steudler, P. A., Melillo, J. M., Aber, J. D., and Bowden, R. D.: Factors controlling atmospheric methane consumption by temperate forest soils, Global Biogeochem. Cycles, 9, 1–10, 1995.

Conrad, R. and Seiler, W.: Influence of temperature, moisture, and organic carbon on the flux of H_2 and CO between soil and atmosphere: Field studies in subtropical regions, J. Geophys. Res., 90, 5699–5709, 1985.

Conrad, R.: Soil microorganisms as controllers of atmospheric trace gases (H_2, CO, CH_4, OCS, N_2O, and NO), Microbiol. Rev., 60, 609–640, 1996

Crutzen, P. J., Sanhueza, E., and Brenninkmeijer, C. A. M.: Methane production from mixed tropical savanna and forest vegetation in Venezuela, Atmos. Chem. Phys. Discuss., 6, 3093–3097, 2006.

Frankenberg, C., Meirink, J. F., van Weele, M., Platt, U., and Wagner, T.: Assessing methane emissions from global space-borne observations, Science, 308, 1010–1014, 2005.

Hao, W. M., Scharffe, D., Crutzen, P. J., and Sanhueza, E.: Production of N_2O, CH_4 and CO_2 from soils in the tropical savannah during the dry season, J. Atmos. Chem., 7, 93–105, 1988.

Hanson, R. S. and Hanson, T. E.: Methanotrophic bacteria, Microbiol. Rev., 60, 439–471, 1996.

Keller, M. and Reiners, W. A.: Soil-atmosphere exchange of nitrous oxide, nitric oxide, and methane under secondary succession of pasture to forest in the Atlantic lowlands of Costa Rica, Global Biogeochem. Cycles, 8, 399–409, 1994.

Keppler, F., Hamilton, J. T. G., Brass, M., and Roeckmann, T.: Methane emissions from terrestrial plants under aerobic conditions, Nature, 439, 187–191, 2006.

Koschorreck, M. and Conrad, R.: Oxidation of atmospheric methane in soil: measurements in the field, in soil cores and in soil samples, Global Biogeochem. Cycles, 7, 109–121, 1993.

Mosier, A. R. and Delgado, J. A.: Methane and nitrous oxide fluxes in grasslands in western Puerto Rico, Chemosphere, 35, 2059–2082, 1997.

Mosier, A., Schimel, D., Valentine, D., Bronson, K., and Parton, W.: Methane and nitrous oxide fluxes in native, fertilized and cultivated grassland, Nature, 350, 330–332, 1991.

Mosier, A. R., Parton, W. J., Valentine, D. W., Ojima, D. S., Schimel, D. S., and Heinemeyer, O.: CH_4 and N_2O fluxes in the Colorado shortgrass steppe 2. Long-term impact of land use change, Global Biogeochem. Cycles, 11, 29–42, 1997.

Poth, M., Anderson, I. C., Miranda, H. S., Miranda, A. C., and Riggan, P. J.: The magnitude and persistence of soil NO, N_2O, CH_4, and CO_2 fluxes from burned tropical savanna in Brazil, Global Biogeochem. Cycles, 9, 503–513, 1995.

Ramaswamy, V., Boucher, O., Haigh, J., Hauglustaine, D., Haywood, J., Myhre, G., Nakajima, T., Shi, G.Y., and Solomon, S.: Radiative forcing of climate change, in: Climate Change 2001. The Scientific Basis, Cambridge University Press, Cambridge, UK, 349–416, 2001.

Sanhueza, E., Cárdenas, L., Donoso, L., and Santana, M.: Effect of plowing on CO_2, CO, CH_4, N_2O and NO fluxes from tropical savannah soils, J. Geophys. Res., 99D, 16 429–16 434, 1994a.

Sanhueza, E., Donoso, L., Scharffe, D., and Crutzen, J. P.: CO fluxes from natural, managed or cultivated savannah grassland, J. Geophys. Res., 99D, 16 421–16 427, 1994b.

Scharffe, D., Donoso, L., Crutzen, P. J., and Sanhueza, E.: Soil Fluxes and atmospheric concentrations of CO and CH_4 in the northern part of the Guayana shield, Venezuela, J. Geophys. Res., 95D, 22 475–22 480, 1990.

Seiler, W., Conrad, R., and Scharffe, D.: Field studies of methane emission from termite nests into the atmosphere and measurements of methane uptake by tropical soils, J. Atmos. Chem., 1, 171–186, 1984.

Striegl, R. G.: Diffusional limits to the consumption of atmospheric methane by soils, Chemosphere, 26, 715–720, 1993

Zepp, R. G., Miller, W. L., Burke, R. A., Dirk, A., Parsons, B., and Scholes, M. C.: Effects of moisture and burning on soil-atmosphere exchange of trace carbon gases in a southern African savanna, J. Geophys. Res., 101, 23 699–23 706, 1996.

Table 1. Methane fluxes from the soil-grass system in the tropical savanna.

Location	Type of grass	Flux (ng m^{-2} s^{-1}) Dry season	Wet season	Reference
Calabozo, Natural savanna	*Trachypogon sp.*		6.0 (–6 to 23)[a] SM[b]: 3–8%	This work
Calabozo Managed savanna	Mixed, mainly *Trachypogon sp.*	10.6 (2 to 15)[a] SM: 1–10%		Sanhueza et al. (1992)
Chaguarama, Natural savanna	*Trachypogon sp.*	11.4 (0.5 to 27)[a] SM: <1%		Hao et al. (1988)
Guri, Natural savanna	Mixed, mainly *Trachypogon sp.*		9.3 (–2.6 to 23)[a] SM: 5–40%	Scharffe et al. (1990)
South Africa Natural savanna	*Hypertelia dissoluta; Elionurus argenteus; Hyparrhenia hirta*	∼5 SM: low		Zepp et al. (1996)

[a] average (range);
[b] soil moisture

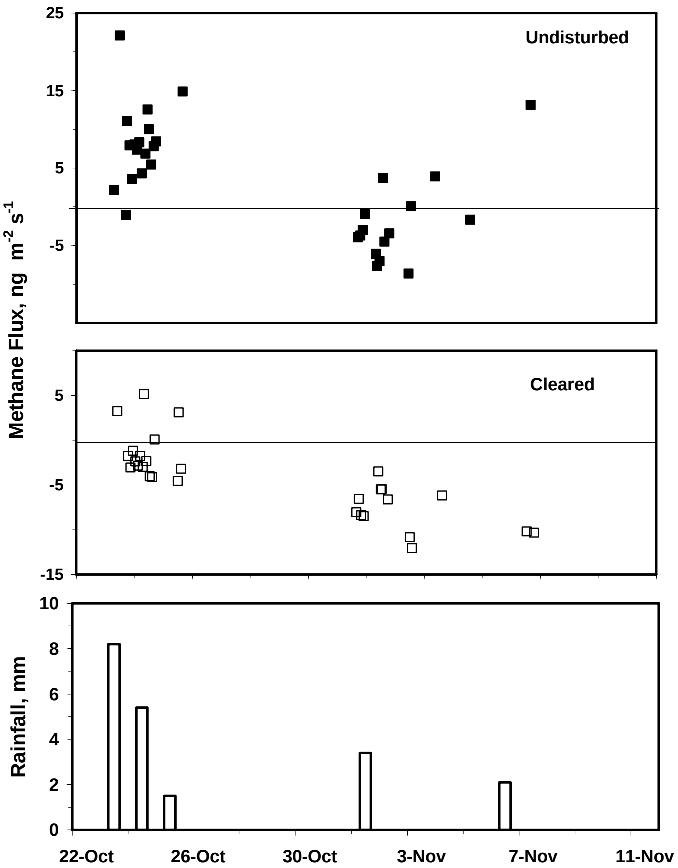

Fig. 1. Methane fluxes from undisturbed and cleared plots. The amount of rainfall is also given.

ACPD

6, 6841–6852, 2006

Methane emission from savanna grasses

E. Sanhueza and L. Donoso

EGU

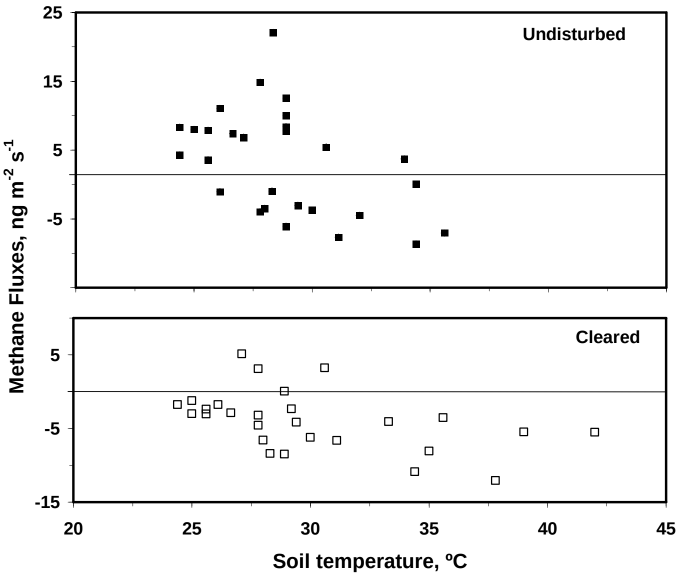

Fig. 2. Methane fluxes as a function of soil temperature in both undisturbed and cleared plots.

ACPD
6, 6841–6852, 2006

Methane emission from savanna grasses

E. Sanhueza and L. Donoso

EGU